999

SIMON HYDRO-SEARCH

5250 South Virginia Street
Suite 280
Reno, NV 89502
Telephone (702) 829-1200
(800) 347-4937
Facsimile (702) 829-1243

Preliminary Characterization of the Hydrology and Water Chemistry of the Sunnyside Mine and Vicinity, San Juan County, Colorado

February 11, 1992

Prepared for:

San Juan County Mining Venture
Washington Mining Company - Operator
P.O. Box 177
Silverton, Colorado 81433

Prepared by:

Simon Hydro-Search
5250 South Virginia, Suite 280
Reno, Nevada 89502

(702) 829-1200
(800) 347-4937

Mark D. Stock
Senior Hydrogeologist
Project Manager

Bob Walston /KAS
Hydrogeologist, P.E.

sanjuan\sunny\110361\oct91.Rpt

SIMON Environmental

TABLE OF CONTENTS

TABLE OF CONTENTS Con't

FIGURES

TABLES

TABLE OF CONTENTS Con't

APPENDICES

1.0 EXECUTIVE SUMMARY

The Sunnyside Mine is located approximately 8 miles north of Silverton in northernmost San Juan County, Colorado. Slightly acidic water containing mobilized heavy metals flows out of both access tunnels to the mine. The purpose of this report is to present a conceptual hydrologic model of the mine vicinity so that the San Juan County Mining Venture (SJCMV) may be able to devise a long term plan which will allow a return to an approximation of pre-mine hydrologic conditions.

Ground water in the bedrock flow system in the vicinity of the Sunnyside Mine is transmitted via fracture permeability. The pre-mining static water level in the bedrock flow system beneath Sunnyside Basin is estimated to have been at an elevation of approximately 11,500 feet above mean sea level based on the water level in the Sunnyside Mine after almost 20 years of inactivity. The majority of flow in the deep ground-water system moved southwest from the Sunnyside Basin to discharge within the Cement Creek watershed. This ground water passed through fractures in rocks containing large quantities of metal sulfides-both along highly mineralized fractures and disseminated throughout the rock. The dissolved metals content of the ground water generally increased downgradient within the ground-water flow system. In the vicinity of Cement Creek springs derived from ground water which had traversed the deep flow system are estimated to have had a pH of less than 5.0 and elevated concentrations of lead, zinc, cadmium, manganese and iron. The chemistry of the base flows of area creeks would have been similar to the chemistry of the springs supplying that base flow. The average flows of area

creeks would be augmented by surface runoff of differing chemistry. However, many surface drainages pass over sulfide-bearing rocks and some have a pH as low as 4.4.

The permeability characteristics of the majority of the ground-water flow system have not been affected by the excavation of the underground workings of the Sunnyside Mine. Dewatering of the mine has reduced the hydraulic head by about 850 feet and locally induced a ground-water gradient toward the underground workings. Most ground water entering the underground workings flows out of the American Tunnel; in effect taking a faster flow path to the Cement Creek watershed than it would have had under natural gradients.

Flow from the American Tunnel portal (at the lowest level of the mine) was measured at 3.1 million gallons per day (mgd) in October of 1991. In the deeper parts of the American Tunnel (farther than approximately 2500 feet from the portal) the majority of water transmitted to the tunnel originates from a few major fracture zones. Minor joints transmit a significant amount of water only in the first 2500 feet of the tunnel. More than half of the discharge of the American Tunnel enters the tunnel downstream of the SJCMV property line.

A large percentage of the surface water from the head of Eureka Gulch drains into the underground workings of the Sunnyside Mine via the Lake Emma Hole and other locations where workings intersect the land surface. The majority of the surface water entering the mine drains to Eureka Gulch via the Terry Tunnel (approximately 900 feet above the level of the

American Tunnel). Measured flow from the Terry Tunnel now varies from 82 gpm in autumn to at least 1400 gpm during spring runoff.

Drainage from both the American Tunnel and the Terry Tunnel is slightly acidic and contains elevated concentrations of metals. Although some of the metals content of the discharge from the American Tunnel is the result of sulfides exposed within the underground workings, much of the dissolved metals load is due to the natural metals content of ground water entering the tunnel. Much of the total metals content in the American Tunnel discharge originates from water entering the tunnel downstream of the SJCMV property line. Most, but not all, of the acid and metals content of drainage from the Terry Tunnel is a direct result of surface water reacting with sulfides exposed by mining.

Drainage from both access tunnels is presently being treated with lime which both increases the pH and precipitates heavy metals. The resulting sludge is transported in tanker trucks to the tailings facility near the Mayflower Mill.

2.0 INTRODUCTION

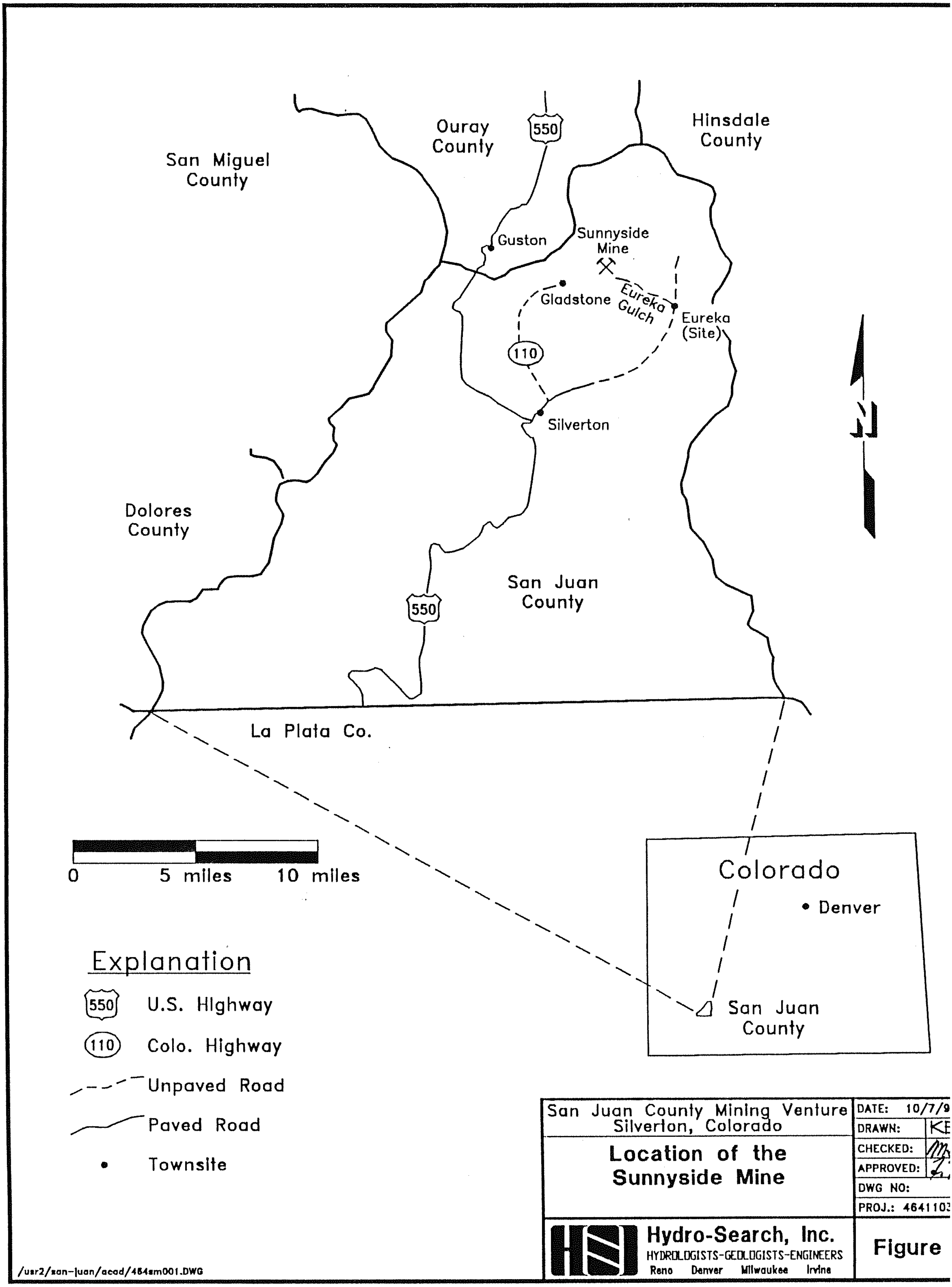
2.1 Location and Brief Description of the Sunnyside Mine

The Sunnyside Mine is located approximately 8 miles north of Silverton in the Eureka mining district in northernmost San Juan County, Colorado (Figure 1). Gold, silver, copper, lead, zinc, and cadmium ores have been produced from more than 150 miles of underground workings with a vertical extent of 2000 feet. The majority of the mine workings are located beneath Sunnyside Basin at the head of Eureka Gulch. Year-round access to the main part of the mine is via the 10,000 foot long American Tunnel, the portal of which is located at an elevation of 10,617 feet at the abandoned townsite of Gladstone. Secondary access is via the Terry Tunnel located in Eureka Gulch at an elevation of approximately 11,560 feet. The jeep trail to the Terry Tunnel is impassible during winter and spring.

2.2 Statement of Problem

As a result of water reacting with sulfide bearing rocks, drainage from both the American Tunnel and the Terry Tunnel is low pH and contains mobilized heavy metals. The San Juan County Mining Venture (SJCMV), owners of the Sunnyside Mine, would like to alter present flow patterns and/or water chemistry in order to reestablish approximate pre-mine hydrologic conditions.

In order to return to an approximation of pre-mine hydrology, it is first necessary to deduce the pre-mine hydrologic conditions. Present conditions must also be understood so that it will be



Ouray County
Hinsdale County
San Miguel County
550
Guston
Sunnyside Mine
Gladstone
Eureka Gulch
Eureka (Site)
110
Silverton
Dolores County
San Juan County
550
La Plata Co.
0
5 miles
10 miles
Colorado
Denver
San Juan County
Explanation
550 U.S. Highway
110 Colo. Highway
Unpaved Road
Paved Road
Townsite
San Juan County Mining Venture
Silverton, Colorado
Location of the Sunnyside Mine
Hydro-Search, Inc.
HYDROLOGISTS-GEOLOGISTS-ENGINEERS
Reno Denver Milwaukee Irvine
DATE: 10/7/9
DRAWN:
CHECKED:
APPROVED:
DWG NO:
PROJ.: 464110
Figure
/usr2/san-juan/acad/464sm001.DWG

possible to devise a long term plan to deal with mine water discharge.

2.3 Scope of Report

The purpose of this report is to present a conceptual hydrologic model, including geochemistry, of the Sunnyside Mine area. The pre-mine ground- and surface-water hydrologic conditions are estimated, and the present hydrology, including flow within the mine workings, is summarized. This report is intended to be a source document which may be useful when formulating plans for dealing with drainage from the underground workings of the Sunnyside Mine.

2.4 Methods

Simon Hydro-Search bases this report on extensive review and analysis of published literature, mine records, files of public agencies, and field work at the Sunnyside Mine. Field work included a visual estimate of flow rates of drainages entering the mine, at various locations within the mine, at adjacent mine portals not owned by SJCMV, and at surface springs and seeps. Water temperature, pH, and electrical conductivity were measured at selected points.

Geologic features pertinent to hydrogeology were noted, such as the nature and orientation of faults, extent of mineralization and weathering, and geologic controls on springs and limonitic staining. Qualitative assessments were made of permeability of wall rock at selected locations within the underground workings.

3.0 HYDROLOGY PRIOR TO MINING

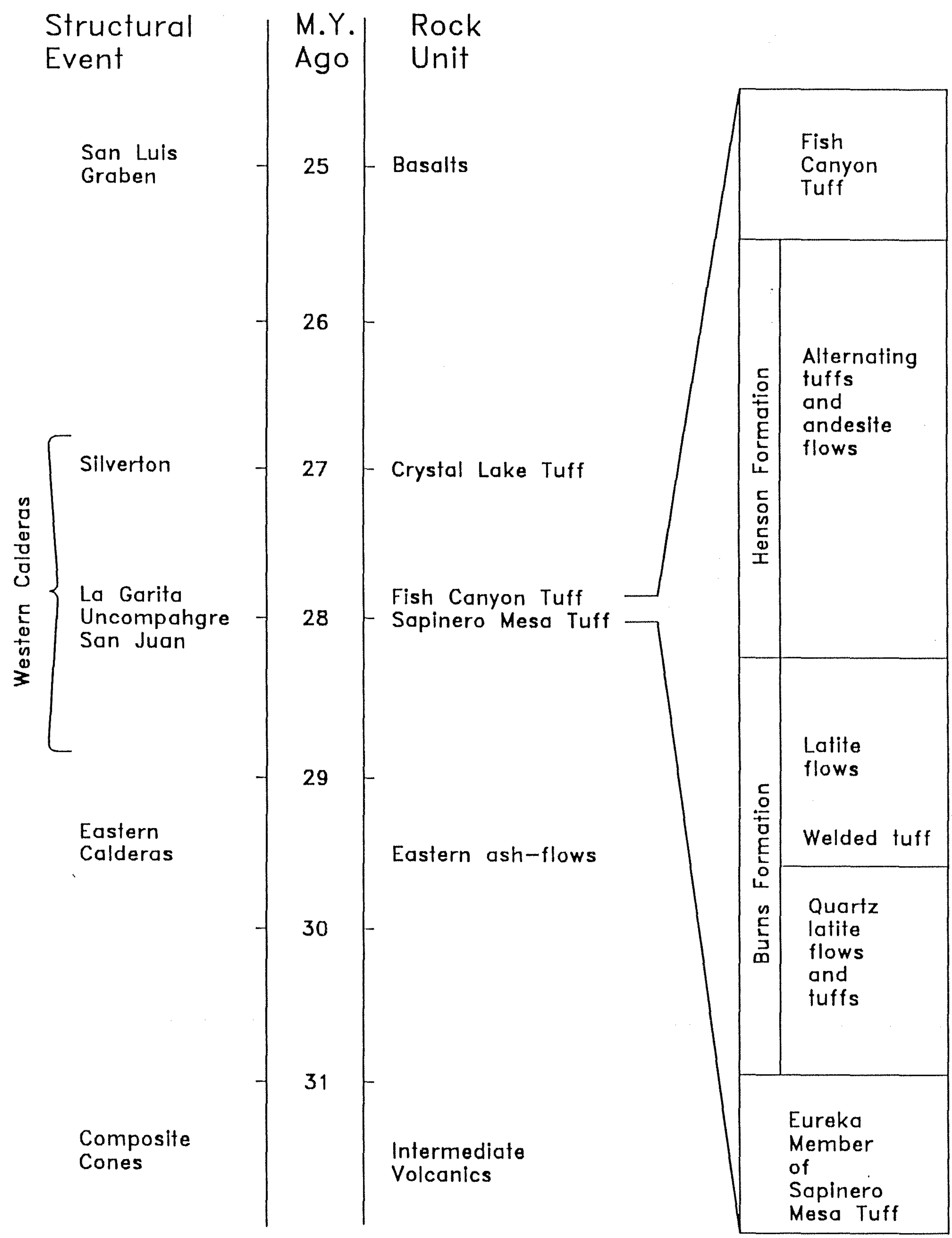
3.1 Pre-Mining Ground-Water Hydrology

3.1.1 Geology Pertinent to Ground-Water Flow and Chemistry

Rocks in the vicinity of the Sunnyside Mine are pyroclastics and flows which erupted from local calderas approximately 28 million years ago (Steven and Lipman, 1976). Local stratigraphy is summarized on Figure 2. The Sunnyside Mine is principally located within the Burns Formation, which generally consists of massive silica-rich latite flows which have locally been altered and mineralized. (Langston, pp. 34-39). The highest mine workings (above A level) extend into the overlying interbedded lava flows and air-fall tuffs of the Henson Formation, an alkali-rich andesite (Langston, p. 49).

The Burns Formation was erupted from vents within the San Juan caldera (Steven and Lipman, 1976, p. 11-12). The degree of welding of the upper Burns formation generally increases towards the west in the direction of the vent source (Langston, 1978, p. 11). The Henson Formation also was derived from vents located within the San Juan caldera, but typically is less welded than the Burns Formation and contains more pyroclastic units.

The extent of fracturing in volcanic rocks is directly related to the degree of welding if other factors are equal. Hence, the Burns Formation tends to be more fractured than the Henson Formation. The fact that many of the major veins in the Burns Formation pinch out approximately at the contact with the Henson (p. 68, Sunnyside Gold Corporation, 1985) may



G:\SAN-JUAN\ACAD\464CH001.DWG

Modified from Langston, 1978

San Juan County Mining Venture
Silverton, Colorado

Stratigraphic Column in the Vicinity of Sunnyside Mine, San Juan County, Co

Hydro-Search, Inc.
HYDROLOGISTS-GEOLOGISTS-ENGINEERS
Reno Denver Milwaukee Irvine

DATE:	10/10/
DRAWN:	KE
CHECKED:	
APPROVED:	
DWG NO:	
PROJ.:	4641103

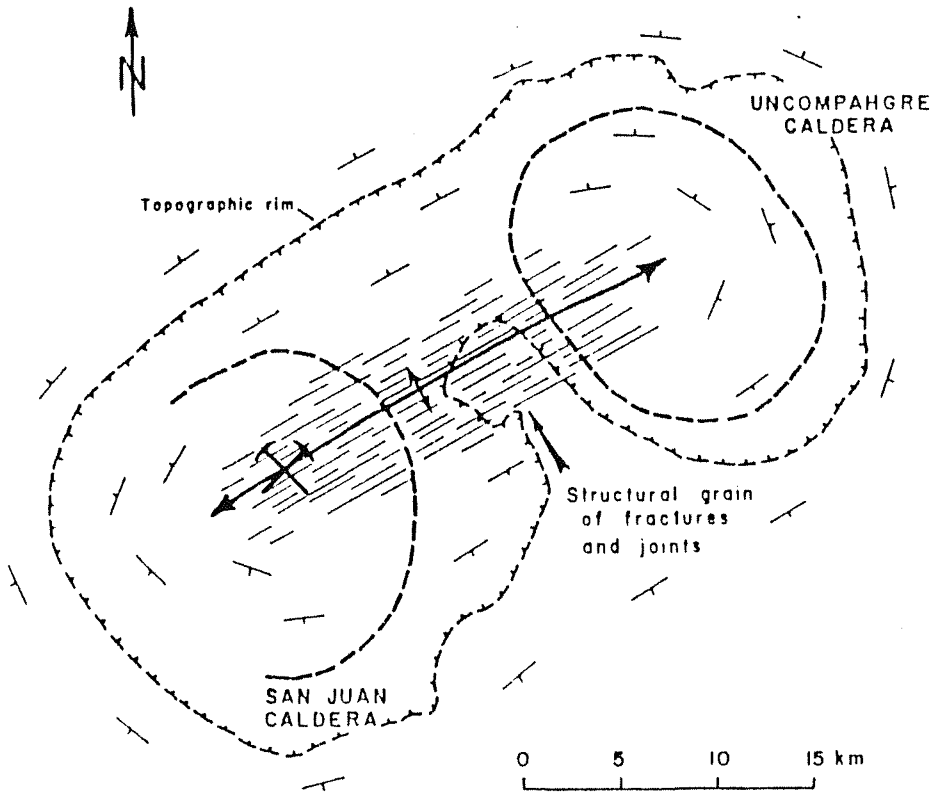
Figure

be explained by the lower degree of welding of the Henson Formation.

After the deposition of the Burns and Henson formations there was a broad resurgent doming between the San Juan caldera and the Uncompahgre caldera. This resurgent doming resulted in extensive distension fracturing in a northeast/southwest-trending direction (Steven and Lipman, 1976, p. 13) as shown in Figure 3. Later collapse of the resurgent doming along steeply dipping, northeast/southwest-trending fractures formed the Eureka graben. Arcuate faults related to the collapse of the Silverton caldera (such as the Bonita fault) appear to be contemporaneous with the bounding faults of the Eureka graben. Although some later faulting exists, the Eureka graben fracture system was the last major set of fractures imprinted on the area of the Sunnyside Mine. During mineralization 13.0 to 16.6 MYBP (Casadevall and Ohmoto, 1977), the fractures of this system served as flow conduits and sites for ore deposition.

The Sunnyside Mine is located within the Eureka graben at the junction of the Ross Basin fault and the Sunnyside fault as shown in Figure 4. Figure 4 also illustrates the dominant northeast/southwest fracture trend. In the vicinity of the mine, the dip of originally horizontal strata now ranges from 10° to 14° to the southwest (Langston, 1978, p. 17).

Rock alteration and mineralization is widespread in the vicinity of the San Juan caldera. "Propylitic alteration has affected many cubic miles of volcanic rocks throughout and beyond the [Silverton] caldera" (Burbank, 1960). In the propylitized rocks "pyrite is ubiquitous and forms between 0.1 and 2.0 percent" of the rock volume (Casadevall and Ohmoto, 1977, p.



Present location of Sunnyside Mine

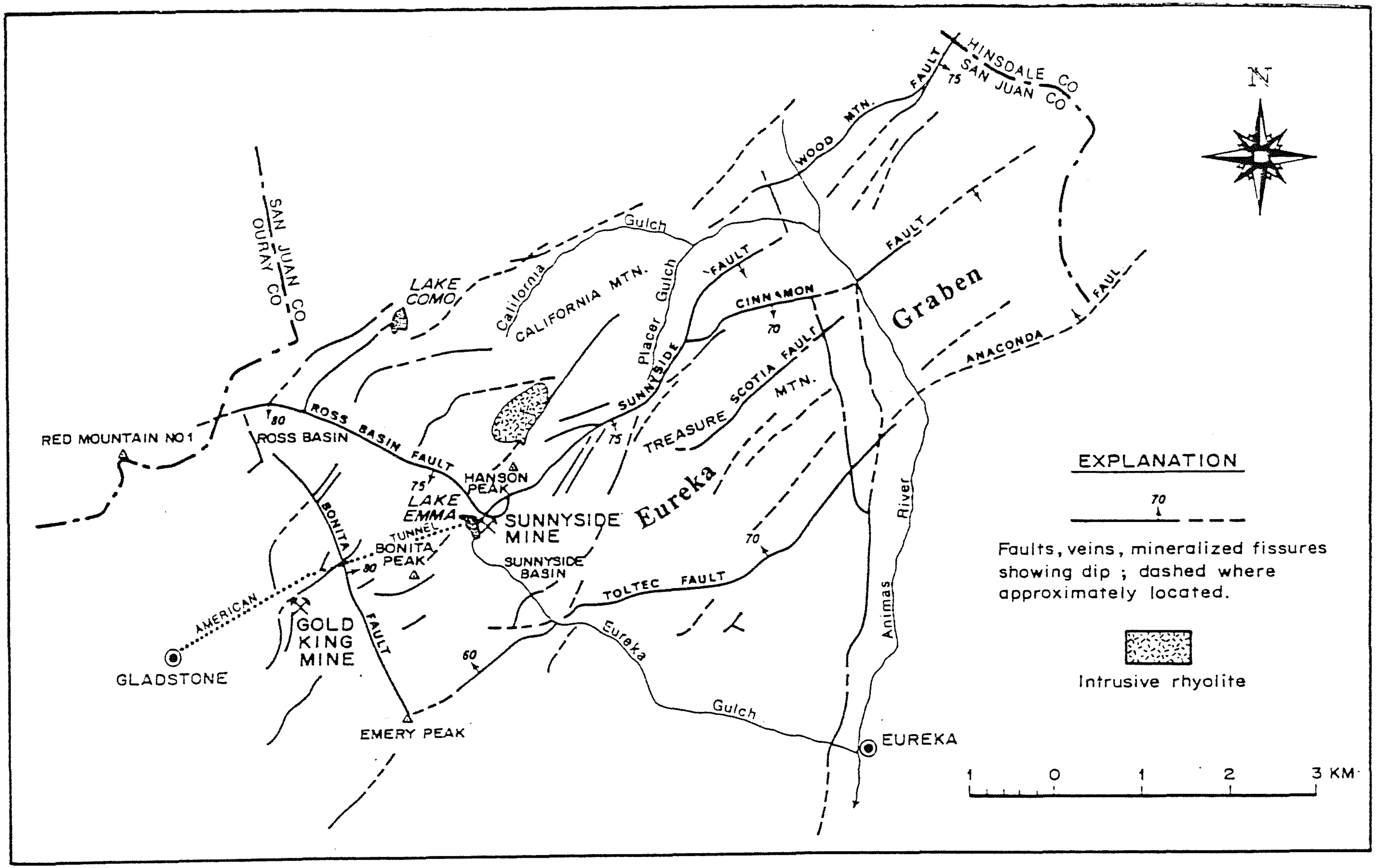
Approximate Axis of Resurgent Doming

Trend of Distension Fracture

Taken from Langston, 1978

San Juan County Mining Venture Silverton, Colorado	DATE: 10/10/9
	DRAWN: KEH
Dominant Fracture System of the San Juan Caldera	CHECKED:
	APPROVED:
	DWG NO:
	PROJ.: 46411036
Hydro-Search, Inc. HYDROLOGISTS-GEOLOGISTS-ENGINEERS Reno Denver Milwaukee Irvine	**Figure 3**

G:\SAN-JUAN\ACAD\464SH002.DWG



San Juan County Mining Venture Silverton, Colorado	DATE: 10/10/91
	DRAWN: KEK
Structural Geology in the Vicinity of the Sunnyside Mine, San Juan County, Co.	CHECKED: MDS
	APPROVED: [illegible]
	DWG NO:
	PROJ.: 464110361
Hydro-Search, Inc.	Figure 4

1292). In excess of one billion tons of pyrite are estimated to exist in rocks in the vicinity of the Sunnyside Mine (assuming 5 cubic miles of propylitzed rocks with 1.0% pyrite). The weathering of this dispersed pyrite as well as other mineralization has resulted in the pervasive staining which is common in rocks throughout the area (e.g. Red Mountains 1, 2, and 3).

3.1.2 Bedrock Permeability

Permeability is the measure of the ability of a rock or soil to transmit a fluid (usually water) under a hydraulic gradient (Lohman, 1979). Much can be inferred about the permeability in the vicinity of the Sunnyside Mine based on site geology and hydrogeologic observations.

The intergranular permeability of pyroclastic sediments is typically very low and the intergranular permeability of volcanic flows and tuffs is insignificant. Freeze and Cherry (1979, p. 29) estimate the range of intergranular permeability of igneous rocks as varying from approximately 10^{-8} cm/sec to less than 10^{-11} cm/sec. In such rocks the vast majority of water is transmitted via secondary fracture permeability. The permeability of fractured igneous rocks ranges from 10^{-6} cm/sec to greater than 10^{-2} cm/sec. The location, extent, openness, and orientation of fracturing controls the hydraulics of the bedrock flow system.

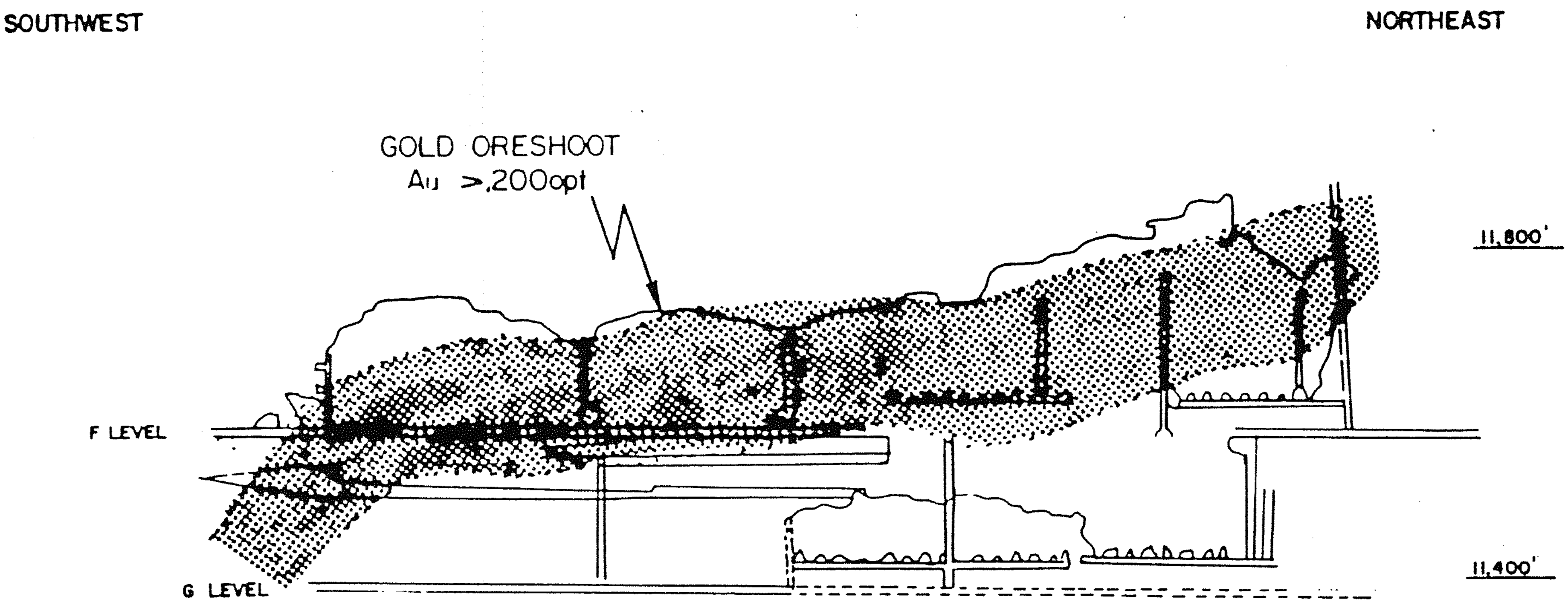
Fracture permeability in the vicinity of the Sunnyside Mine is anisotropic. Permeability is greater in a northeast/southwest direction due to the dominant fracture orientation within the Eureka graben (see section 3.1.1). In addition, fracture permeability is greater in the welded tuffs and flows than in the unwelded units. The southwest dip in the vicinity of the mine results

in zones of greater permeability which dip southwest along the more highly fractured units. The overall effect is that the greatest permeability zones trend northeast/southwest and dip about 10° - 14° southwest. Field evidence for this anisostropy in permeability includes a preferred orientation for ore shoots. Figure 5 shows an example of a northeast/southwest trending ore shoot which dips southwest.

The fracture permeability in the vicinity of the mine is inhomogeneous. In the upper Burns Formation fracture permeability is expected to increase from Sunnyside Basin toward Cement Creek as strata become more welded (now fractured) in the direction of the original volcanic vent (see section 3.1.1).

Fracture permeability generally decreases with depth as the fractures are progressively sealed by increasing overburden pressure. Evidence for this can be observed in both the American Tunnel and the Terry Tunnel. At locations deep within the mine water enters each tunnel only where major fractures are encountered, and most of the back and rib of the tunnel is dry. However, as the portals are approached decreasing overburden pressure allows relatively minor joints to transmit water and dripping water becomes common.

In the deeper parts of the flow system significant quantities of water are transmitted only by major fractures. This is demonstrated by the fact that the deeper part of the present American



LONGITUDINAL CROSS-SECTION
2150 VEIN

0 SCALE IN FEET 400'

San Juan County Mining Venture Silverton, Colorado	DATE: 10/21/91 DRAWN: KEK
A Southwest Raking Ore Shoot on the 2150 Vein Sunnyside Mine	CHECKED: MDS APPROVED: F. Fox DWG NO: PROJ.: 464110381
Hydro-Search, Inc. HYDROLOGISTS–GEOLOGISTS–ENGINEERS	Figure 5

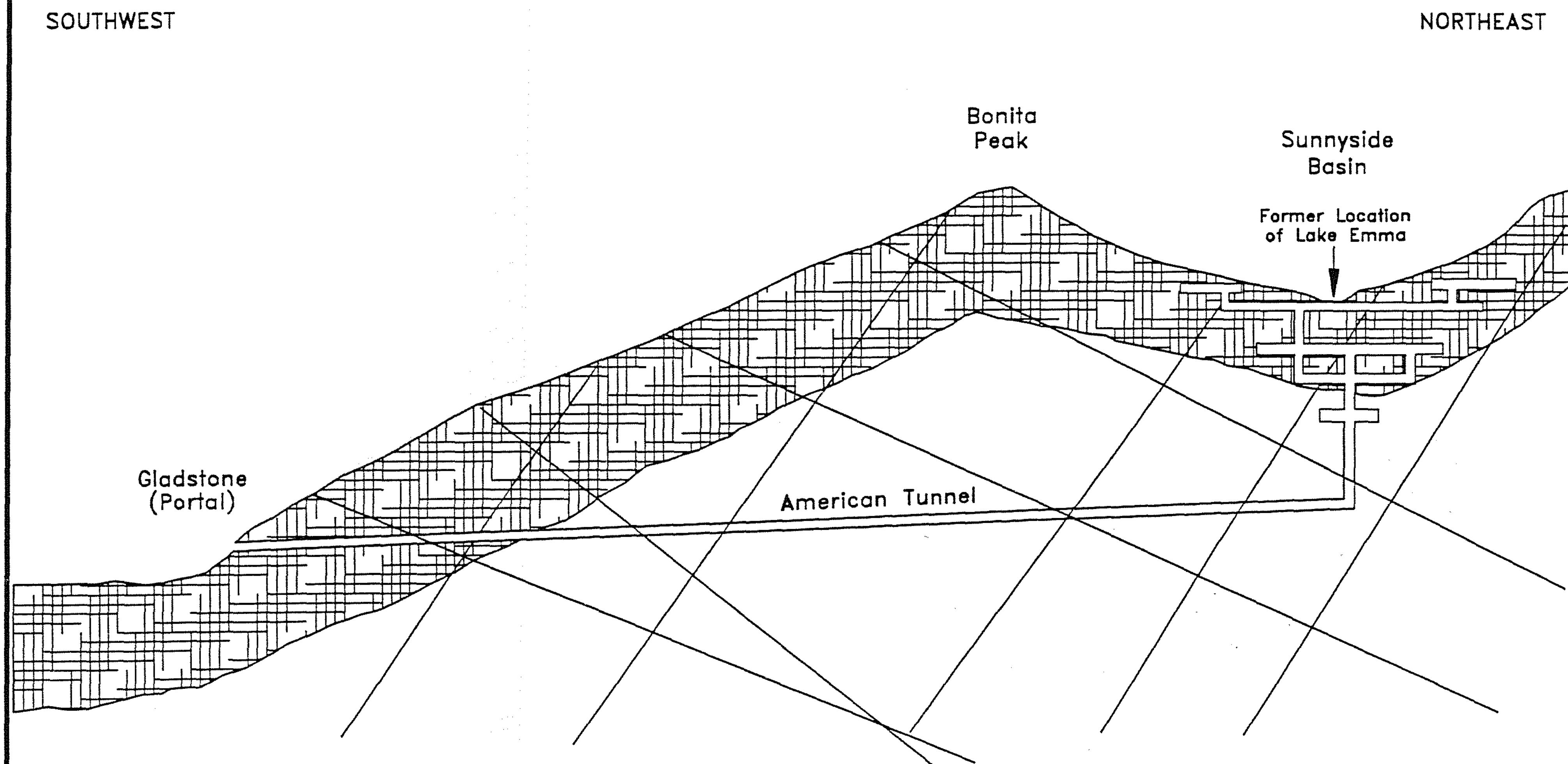
Figure from Sunnyside Gold

Tunnel (beyond the Daylight Corner at approximately 2700 feet from the outside end of track[1]) has intercepted 1350 gpm of ground water. Of this 1350 gpm, 90 percent can be accounted for from the intersection of five major fracture zones (the Washington vein, the Sunnyside vein, the Brenneman vein, a fracture zone at the 0700 runaround, and a fracture zone located 3020 to 3220 feet from the end of track (see section 4.2.1). Figure 6 is a schematic diagram showing the manner in which fracture permeability changes with depth.

A dramatic demonstration of the localized nature of the fracture permeability in the deeper parts of the mine occurred when the American Tunnel first intercepted the Washington vein. During the late 1950's workings above the American Tunnel were flooded to approximately 50 feet below F Level according to Mr. Bob Ward, mine superintendent of the Sunnyside Mine at that time. This resulted in approximately 830 feet of hydraulic head over the American Tunnel. Diamond drilling was used to intercept the Washington vein from the face of the American Tunnel. When the vein was intersected the sustained water pressure and volume were so great that the full 150 feet of drill string was pushed back out of the hole into a twisted "spaghetti" of steel. A day later flow out of the 2-inch diameter hole was under enough pressure to shoot out approximately 20 feet from the drill hole. The estimated flow of water was approximately 580 gpm (see Appendix A). The nearest old workings on the Washington vein were located on I Level, approximately 350 feet higher than the American Tunnel. This indicates a very high permeability along the vein.

---

[1] All footages along the American Tunnel are referenced to track repair footages as marked on the tunnel wall. The track repair footages have a zero point just outside of the portal.



EXPLANATION

Zone where minor fractures transmit significant quantities of water.

Major fractures which transmit water even under considerable overburden pressure.

Mine workings.

San Juan County Mining Venture Silverton, Colorado	DATE: 10/23/91
	DRAWN: DRD
Schematic of Differing Fracture Permeability With Depth	CHECKED: MDS
	APPROVED: F. Fox
	DWG NO:
	PROJ.: 464110381
Hydro-Search, Inc. HYDROLOGISTS–GEOLOGISTS–ENGINEERS	**Figure 6**

3.1.3 Bedrock Storage Coefficient

The storage coefficient is related to the interconnected porosity of a rock and is defined as the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the hydraulic head (Driscoll, 1986). The storage coefficient is dimensionless.

Crystalline volcanic rocks have very low primary porosity, but can develop moderate secondary porosity due to development of fractures (Freeze and Cherry, 1979). For unconfined conditions, storage coefficients are approximately equal to the effective porosity and range from 0.01 to 0.3. For confined conditions storage coefficients range from 0.001 to 0.00001 (Driscoll, 1986). The upper part of the zone of saturation is expected to be unconfined, and the deeper part of the flow system is expected to be confined by poorly welded zones of low permeability.

The storage coefficient can also be estimated using the relationship that storage coefficient varies directly with the thickness of the aquifer. The rule-of-thumb relationship from Todd (1980, p. 46) is as follows:

$$\text{Storage coefficient} = 3 \times 10^{-6} \times \text{aquifer thickness}$$

Based on the above relationships and past experience in volcanic terrains, the storage coefficient probably ranges from 0.01 to 0.005.

3.1.4 Pre-Mining Potentiometric Surface

Simon Hydro-Search has used observations from 1959 and 1961 to estimate the equilibrium static water level beneath the Sunnyside Basin. Mr. Bob Ward (mine superintendent during construction of the American Tunnel) personally saw that the static water level in the Washington Inclined Shaft was approximately 50 feet below F level during the summer of 1959. Mr. Ward's recollection appears reasonable in light of a letter from D. Hutchinson to Messrs. William R. McCormick and Robert M. Hurst dated February 3, 1961. This letter states that during January of 1961 (after the American Tunnel had intersected some of the fractures under the old workings) "the water was 97 feet below F level and falling 3½ feet per day". The observed water levels in 1959 and 1961 were below F level where drainage to the surface would have occurred via the Terry Tunnel. The 1959 static water level reflects a lack of dewatering during the preceding 20-year period during which time the mine was inactive. The 1959 static water level is thought to represent an equilibrium condition of inflow to the workings versus outflow via natural fracture permeability. It is worth noting that this static water level is deep enough that most of the minor joints would be sealed by the overburden pressure (see Section 3.1.2).

Direct surface-water inflow to the mine in 1959 was far less than today. Hence, the static water level in 1959, estimated at 11,500 feet above mean sea level (msl), is assumed to approximate the static water level in the fractured bedrock prior to commencing mining.

Lake Emma was a glacial tarn in Sunnyside Basin at an elevation of approximately 12,250 feet msl. On June 4, 1978 Lake Emma drained into workings on the Spur vein causing extensive damage throughout the mine (Bird, 1986, p. 135). In areas of high permeability a lake can usually be considered to represent the water table. However, this does not appear to have been the case for Lake Emma. Two samples of the lacustrine clays which formerly were under Lake Emma were tested in August 1988 and shown to have permeabilities ranging from 1.6 x 10^{-7} to 6.7 x 10^{-9} cm/sec under 95% relative compaction (see Appendix B). These permeability values are very low and little water would have been transmitted through such material. Lake Emma is considered to have been perched on low permeability lacustrine clays and/or poorly fractured Henson Formation.

Prior to the existence of the mine the gradient was approximately 0.1 feet/foot from the head of Sunnyside Basin to either Cement Creek, at Gladstone, or to the Animas River at the site of Eureka (see Table 1). If the pre-mine hydraulic head under Sunnyside Basin had been higher or lower the hydraulic gradient would have a different value, but the rate of change in gradient would be about the same to the southeast (toward Midway Mill site) as to the southwest (toward Gladstone).

If permeability had been homogeneous and isotropic the ground water might have moved in either direction. However, as discussed in section 3.1.2 a strong anisotropy exists with enhanced permeability both in a northeast/southwest direction and also dipping southwest. In

Table 1. Estimated Pre-Mine Ground-Water Gradient within the Fractured Bedrock			
	Elevation[1] (feet msl)	Distance[1] from Workings under Sunnyside Basin (feet)	Gradient[2] from head of Sunnyside Basin to indicated point
Cement Creek near Portal of American Tunnel	10,500	9,500	0.105
Discharge Zone near Mogul Mine Portal	11,250	6,300	0.040
Animas River at Site of Eureka	9,850	15,600	0.106
Eureka Gulch near Midway Mill Site	10,480	9,300	0.110

1) Estimated from U.S.G.S. Handies Peak and Ironton 7 1/2 minute quadrangles

2) Assumes the pre-mine hydraulic head in the fractured bedrock beneath Lake Emma was approximately 11,500 feet above mean sea level (based on the 1959 water-level observation of Mr. Bob Ward).

addition, greater fracture permeability associated with a higher degree of welding of the volcanics is expected beneath the Gladstone area than beneath the Sunnyside Basin. The local anisotropy and inhomogeneity of the fracture permeability would facilitate ground-water movement toward Cement Creek. Hence, the majority of water in the bedrock flow system is inferred to have moved from the Sunnyside Basin to the Cement Creek drainage where it discharged as springs and seeps.

Field evidence supports the idea that the preferred ground-water flow direction is southwest rather than southeast in the vicinity of the Sunnyside Mine. Field observations by Simon Hydro-Search staff during July and August, 1991 located a greater number of visible springs and seeps in the Cement Creek drainage, above Gladstone, than in Eureka Gulch. Furthermore, the springs and seeps in the two forks of Cement Creek above Gladstone are preferentially located on the east side of the creek, indicating a source to the east is most likely. Finally, based on the volume of dumps, the Silver Ledge Mine, located on the east side of the South Fork of Cement Creek, appears to have approximately the same extent of underground workings as the Big Colorado Mine located on the adjacent opposite side of creek. Yet, based on the present flow from the portals, the Silver Ledge Mine intercepted approximately ten times as much water as the Big Colorado Mine.

3.1.5 Pre-Mining Ground-Water Chemistry

Prior to any mining, ground water in the vicinity of the Sunnyside Mine is thought to have had a higher level of dissolved metals and a lower pH than ground water in unmineralized areas.

The anomalous metals content and low pH was caused by the oxidation of sulfides along fractures - both mineralized fractures and fractures with only the background disseminated sulfides. These oxidation reactions are responsible for the extensive limonitic staining so common in the San Juan Mountains (e.g. Red Mountains 1 and 3 adjacent to Gladstone).

The chemistry of ground water can be measured from samples from wells and springs. No deep wells exist in the vicinity of the Sunnyside Mine, but chemical parameters have been measured at springs in the Cement Creek drainage, and discharge from fractures within the Sunnyside Mine.

Table 2 summarizes selected chemical parameters of waters entering the American Tunnel. Most of the water in the vicinity of Washington Inclined Shaft (Washington vein, West Drift, and Sunnyside Drift) originates as ground water which has entered the fracture-flow system in or near the Sunnyside Basin and has had a relatively short flow path to the mine workings. Ground water from Fault #1 and Fault #2 seems to have traversed a greater distance from the recharge area.

Water from the Hanging Wall Drift of the Washington vein is slightly warmer than other mine flows and is expected to contain some ground water rising from depth. This rising of ground water may be induced by the decrease in hydraulic head associated with dewatering the mine. This water should not contain elevated levels of metals or acid caused by exposure of sulfides

Table 2: Selected Chemical Parameters of Waters Entering the American Tunnel Level of the Sunnyside Mine											
Sample Location	Date	Lab	Zn mg/l	Pb mg/l	Mn mg/l	Cu mg/l	Cd mg/l	Fe mg/l	As mg/l	lab pH	Conductivity
Washington Vein Hanging Wall	3/5/91	R&N	0.59	0.19	1.58	0.03	0.005	0.17	---	7.18	---
	3/5/91	IML	0.75	<0.005	2.01	<0.01	0.005	0.07	<0.005	7.54	1860
	3/13/91	IML	0.98	<0.005	2.21	<0.01	<0.002	0.06	<0.005	7.17	1990
	3/13/91	R&N	0.95	0.15	2.18	0.02	0.002	0.22	---	7.53	---
	Average		0.82	0.09	2.00	0.02	0.003	0.13	0.005	1736	1925
Washington Vein Foot Wall	3/5/91	R&N	33.43	0.21	64.29	0.13	0.090	0.38	---	7.68	---
	3/5/91	IML	34.3	<0.005	61.9	<0.01	0.073	<0.05	<0.005	7.24	1850
	Average		33.9	0.11	63.1	0.07	0.082	0.22	0.005	7.46	1850
West Drift	3/5/91	R&N	16.70	0.24	18.65	0.205	0.106	15.5	---	6.73	---
	3/5/91	IML	17.9	<0.005	17.7	<0.01	0.082	5.47	<0.005	6.71	1740
	Average		17.3	0.12	18.2	0.11	0.094	10.5	0.005	6.72	1740
Sunnyside Drift	3/5/91	R&N	0.09	0.18	1.83	0.02	<0.002	0.25	---	7.57	---
	3/5/91	IML	0.09	<0.005	2.10	<0.01	0.003	0.14	<0.005	7.60	1340
	3/13/91	IML	0.06	<0.005	1.87	<0.01	<0.002	<0.05	<0.005	7.18	1430
	3/13/91	R&N	0.07	0.08	1.94	0.01	0.004	0.18	---	7.60	---
	Average		0.08	0.07	1.94	0.01	0.003	0.15	0.005	7.49	1385
Fault #1	3/5/91	R&N	47.08	0.21	91.4	0.34	0.064	334.0	---	5.9	---
Fault #2	3/5/91	R&N	70.1	0.59	132.6	0.03	0.106	531.0	---	6.05	---
Fault #2	3/5/91	IML	92.1	0.425	151	<0.01	0.089	537.	<0.005	---	---

Notes:

[1]R&N is Root & Norton Laboratories of Silverton, Colorado. Analyses are for total recoverable metals.
[2]IML is Inter-Mountain Laboratories, Inc. of Farmington, New Mexico. Analyses are for dissolved metals.

by mining activities, yet it contains relatively high concentrations of lead and manganese. The Sunnyside Cross Cut did not intersect any significant mineralization. Water from the Sunnyside Cross Cut therefore should not be significantly impacted by oxidation of sulfides exposed by mining; yet it also contains relatively high concentrations of lead and manganese. Waters from the West Drift and Footwall Drift may contain a relatively small volume of water which cascades down from open stopes after reacting with exposed sulfides and oxygen. Waters from the West Drift and Footwall Drift should not be considered to represent ground-water chemistry.

Fault #1 and Fault #2 intersect the American Tunnel a little over one half mile from the portal (between track repair footages 3000 and 3250). Ground water entering the tunnel at these locations contains much greater concentrations of dissolved metals and has a lower pH than ground water in the vicinity of the Washington Inclined Shaft. Water from Fault #1 and Fault #2 contains high concentrations of zinc, lead, manganese, cadmium and iron. The increased concentrations of metals and lower pH may be due to a longer flow path or greater residence time within the deep fracture-flow system.

Seeps associated with considerable iron staining of soil are locally known as iron bogs. Such iron bogs are common along both the north and south forks of Cement Creek. The iron staining is due to iron oxides and hydroxides precipitating out of metal laden ground water. There are iron bogs associated with most of the abandoned mine portals, but iron bogs also exist where there are no mines located uphill (such as near the head of the South Fork of Cement Creek). The iron bogs located near abandoned portals may be accentuated by water which has picked

up metals and acid while percolating through sulfide-bearing dumps. However, the presence of iron bogs away from old workings proves that natural seeps also carried anomalous loads of metals (and probably acid). The iron bogs located near old mine workings probably pre-date the workings. Prospectors consider iron staining to be a good indication of mineralization and often drove test tunnels into limonite-stained rock.

Iron bogs are formed as a result of iron-laden ground water discharging as springs and seeps. The relatively low redox potential of ground water allows iron to remain in solution in the subsurface. When iron-laden ground water is discharged to the surface, the iron is oxidized and precipitates as hydroxides and/or oxyhydroxides. Many other heavy metals tend to be adsorbed onto the iron precipitate and are removed from solution. The precipitation process is accompanied by the release of hydrogen ions (Garrells and Christ, 1965, p. 189) which lowers pH. The net effect is that a significant part of the dissolved metals load of ground water is removed from solution soon after the water surfaces, but the water becomes more acidic.

A pH of 4.5 was measured at a sizable natural discharge zone near the Mogul Mine portal on July 31, 1991 by Simon Hydro-Search staff. A pH of 4.24 was measured at the same discharge zone on October 17, 1991 by SJCMV staff. The pH measurements were made at a location which was upstream of the waters flowing from the Mogul Mine portal. This discharge zone appears to be localized by the Bonita fault (see Figure 4). The Bonita fault is perpendicular to the dominant northeast/southwest fracture trend and is expected to intercept ground water from such fractures. A low pH may be typical of water which has traversed the full extent of the

deep fracture-flow system, but the pH values measured at this bog may be less than in the ground-water system due to the precipitation of iron hydroxides.

A pH of 6.0 was measured at a small spring near the head of the South Fork of Cement Creek on August 2, 1991 by HSI staff. This spring may originate from a shallow flow system from nearby snowmelt.

Langston (1978, p. 129-133) estimated that the pH of the water in the Sunnyside vein system was between 3.5 and 5.0 during ore deposition. This estimate was based on the presence or absence of certain mineral species, combined with the measured concentration of dissolved species measured by Casadevall and Ohmoto (1977). Flow conditions were different immediately prior to mining than during ore deposition, but the ores are considered to have been deposited under a relatively local meteoric ground-water flow system (Casadevall and Ohmoto, 1977). The metals which were deposited in the vein systems of the Sunnyside Mine had previously been leached by meteoric water from disseminated minerals in the bedrock located upgradient.

In summary, prior to mining, ground water which had traversed the length of the bedrock flow system appears to have had a pH of less than 5.0 and a dissolved load of metals greater than in unmineralized areas. Ground water near the recharge area had a more neutral pH, yet had a relatively high concentration of lead and manganese.

3.1.6 Recharge to the Ground-Water System

The primary recharge mechanism for the bedrock aquifers in the mountains north of Silverton is infiltration of rain and snowmelt. The average annual precipitation in the upper reaches of Cement Creek and Eureka Creek between 1921 and 1950 was approximately 45 inches, of which approximately 30 inches occurred as snow (Iorns, et al., 1964). A simple water balance can be performed to estimate the amount of annual recharge to the bedrock aquifer by subtracting runoff, sublimation, and evapotranspiration values from the precipitation. The United States Geological Survey has estimated the annual runoff from the high mountain basins north of Silverton at between 10 inches (Longbein, et al., 1949) and 20 inches (Gebert, 1987). The total losses from an alpine snowpack above timberline (via evaporation, sublimination, and wind transport) are approximately 50 to 60% (Meiman and Grant, 1974). Therefore, the total remaining precipitation contributed by snowfall on an average annual basis (1921-1950) is between 12 and 15 inches. Considering the short growing season at high altitude, the average evapotranspiration rate for alpine meadow is expected to be low.

Taking the average of the range of values for precipitation, losses to snowpack, and runoff, the amount of annual precipitation available for recharge to the ground-water system is estimated at 8.5 inches. Using minimum values results in an estimate of only 2 inches of recharge per year.

3.1.7 Discharge from the Ground-Water System

Prior to mining, ground water discharged from the bedrock flow system via springs and seeps in the major drainages. The overall ground-water discharge rate in the Cement Creek watershed and Eureka Gulch was probably very close to the overall recharge rate.

The base flow of the master stream in a watershed equals the total ground-water discharge to the watershed, minus evapotranspiration along creeks and near springs. The base flow of the North Fork of Cement Creek just above Gladstone is presently 230,000 gallons per day (gpd). According to SJCMV records, the base flow of Eureka Creek below the Terry Tunnel is presently somewhat greater than 170,000 gpd (170,000 gpd plus the flow from McCarty Basin).

Dewatering of the Sunnyside Mine may have reduced the flow of some springs and seeps along Cement Creek by reducing the hydraulic gradient toward the springs. Thus, the pre-mine ground-water discharge along Cement Creek was probably significantly greater than today. The recharge estimate of 8.5 inches (Section 3.1.6) indicates that the total pre-mine ground-water discharge should have been approximately 4 ½ times greater. However, the minimum recharge estimate would match present observed flows.

3.2 Pre-Mining Surface-Water Hydrology

3.2.1 Surface-Water Flow

Surface water in the area occurs in small mountain lakes and as stream flow in the drainages. Stream flow varies considerably. High flow rates occur during the spring in response to melting

snow and thunderstorms. The flow in the North Fork of Cement Creek just above Gladstone presently ranges between 15.7 million gallons per day (mgd) at the end of May to 0.23 mgd at the end of January. The flow in Cement Creek above Gladstone may have been greater prior to mining due to increased discharge from springs (see section 3.1.7). The flow in Eureka Creek just below the Terry Tunnel typically ranges from 7.2 mgd in early June to 0.17 mgd in late October. The flow in Eureka Creek was calculated by adding the measured flow above the Terry Tunnel to the measured flow from the Terry Tunnel and does not include the flow from McCarty Basin (which is not measured). The rate of flow in Eureka Creek (below the present portal of the Terry Tunnel) probably has not been significantly affected by mining.

3.2.2 Surface-Water Chemistry

There are no recorded measurements of the water chemistry of Eureka Creek or Cement Creek prior to mining. Early accounts, at the very onset of mining in the 1870's, relate that locally the natural quality of water was so poor that certain streams were "undrinkable" (Rhoda, 1984). This is not surprising considering the tremendous volume of sulfides dispersed throughout the bedrock (see section 3.1.1). These sulfides react with meteoric water to release acid and mobilize metals.

Eureka Creek above the Terry Tunnel is presently neutral (average pH from 1987-1991 was 7.1). Eureka Creek above the Terry Tunnel may have had a lower pH prior to mining because surface drainages flowing over outcrops within the highly mineralized Sunnyside Basin would be expected to have reacted with sulfides. For example, a drainage above the Washington Vein

has shown a mean field pH value of 6.0 over the period 1987-1991. This drainage passes over mineralized bedrock, but does not pass through any mine workings prior to sampling. Water from this drainage shows elevated concentrations of heavy metals including the following average values over the period 1987-1991: 0.0037 mg/l of cadmium, 0.033 mg/l of copper, 0.17 mg/l of lead, and 1.9 mg/l of zinc (Appendix C). The preceding averages assume the detection limit value was present when an element could not be detected. The range of values is large and depends on the quantity of flow, etc. The maximum measured concentrations for the same elements are as follows: 0.012 mg/l of cadmium, 0.17 mg/l of copper, 0.882 mg/l of lead, and 5.9 mg/l of zinc. These surface drainages are now largely routed through the mine workings and out the Terry Tunnel.

Many iron bogs are present in both the North and South Forks of Cement Creek, indicating metal-laden water is, or has been, discharging to Cement Creek. As discussed in section 3.1.5, prior to mining the springs discharging to the Cement Creek drainage above Gladstone probably had a pH of less than 5 and had elevated levels of metals. Therefore, the pH of the base flow of Cement Creek would also have been less than 5.0. The pH and metals content of Cement Creek would have varied depending on snowmelt and precipitation conditions.

As in Sunnyside Basin, many surface drainages which are tributary to Cement Creek pass over mineralized bedrock and react with sulfides. A pH of 4.4 was measured on August 2, 1991 in one such tributary to the South Fork of Cement Creek. No mine development, historical or active, exists upstream of where this measurement was taken.

4.0 PRESENT HYDROLOGY

4.1 Present Ground-Water Hydrology

4.1.1 Bedrock Permeability

The permeability characteristics of the bulk of the ground-water flow system have not been affected by the excavation of the underground workings of the Sunnyside Mine. These characteristics are detailed in section 3.1.2.

Within the voids created by mining the permeability is extremely high, and resistance to flow is mainly a function of the kinematic viscosity of the water. The majority of the underground mine workings are located beneath the Sunnyside Basin within an area extending 4000 feet from east to west, and 2500 feet from north to south. However, the workings now form a direct connection from the ground-water flow system beneath Sunnyside Basin to the Cement Creek watershed via the American Tunnel.

The excavation of the underground workings has involved a tremendous amount of blasting. The fractures induced by blasting for underground mining activities propagate less than 20 feet from the blast site (Siskind and Fumanti, 1974; Worsey, 1985; and Worsey, 1986). Hence, the zone of enhanced permeability due to mining is limited to the immediate vicinity of workings and to a few near-surface areas where workings have self-stoped upwards.

4.1.2 Bedrock Storage Coefficient

The characteristics of the storage coefficient in the bulk of the ground-water flow system have not been affected by excavation of the Sunnyside Mine. These characteristics are described in section 3.1.3.

The storage coefficient will be equal to 1.0 within the voids created by mining. However, the actual volume of voids created by mining is relatively small when compared to the total volume of rock beneath the Eureka and Cement Creek watersheds.

4.1.3 Potentiometric Surface

The present potentiometric surface in the vicinity of the Sunnyside Mine probably resembles the pre-mining potentiometric surface (see section 3.1.4) except in the immediate vicinity of underground workings or major permeable fractures which intersect these workings. The hydraulic head has been decreased in the underground workings by approximately 830 feet based on an equilibrium static water level of approximately 50 feet below F level (see section 3.1.4).

Major permeable fractures have a hydraulic gradient toward the mine workings as indicated by inflow to the American Tunnel level from the Brenneman, Washington, and Sunnyside veins, among others. Within these fractures the high permeability results in a relatively gentle gradient toward the mine workings. Ground water from these fractures would have eventually traveled to natural discharge points along the Cement Creek drainage. Flow from these fractures is, in

effect, taking a faster flow path to the Cement Creek watershed than it would have had under natural conditions.

Adjacent to underground workings in those areas where major fractures do not exist, the hydraulic gradient is very steep in the direction of the mine workings. For example, diamond drill holes oriented perpendicular to the American Tunnel at the 0700 and 1500 "runarounds" encountered water under considerable pressure when they intersected permeable fractures. Some of these diamond drill holes have been partially cased and equipped with valves. Even today, one of these valved holes will spurt over 30 gpm across the full width of the runaround when opened. It is very likely that there are saturated fractures directly above most of the American Tunnel.

4.1.4 Ground-Water Chemistry

The water chemistry of the bedrock flow system has probably not been significantly altered by the presence of the Sunnyside Mine. The water chemistry of the bedrock flow system is described in section 3.1.5. The water chemistry of the open channel flow within the Sunnyside Mine workings is described in section 4.2.2.

4.1.5 Recharge to the Ground-Water System

Recharge to the ground-water flow system (which is not considered to include open channel flow within underground workings) has probably not been significantly affected by the presence of the Sunnyside Mine. There may be a slight decrease in recharge due to the draining of Lake

Emma, which formerly would have been leaking to the ground-water system through low permeability lacustrine clays.

4.1.6 Discharge from the Ground-Water System

The discharge from the ground-water flow system may be temporarily enhanced by the presence of the Sunnyside Mine. As discussed in section 3.1.7 the base flow of Eureka Creek below the Terry Tunnel is now somewhat greater than 170,000 gpd. The base flow of the North Fork of Cement Creek above Gladstone is approximately 230,000 gpd. However, at Gladstone the American Tunnel discharges a flow of approximately 3,100,000 gpd (based on an October 1991 measurement). Most of the flow from the American Tunnel originates as ground water from permeable fractures. The Sunnyside Mine has removed ground water from storage and induced an irregular cone of depression in the potentiometric surface. When recharge to the fractures equals discharge from the fractures an equilibrium will exist in which no more water will be removed from storage. American Tunnel flows mentioned in letters from D. Hutchinson to Messrs. McCormick and Hurst in 1961 are greater (up to 2,500 gpm) than the flow measured by SJCMV in October, 1991 (2,160 gpm), but it is likely that the system is now nearly at equilibrium. If the drainage of these fractures has not yet reached equilibrium, then discharge from the ground-water flow system has been temporarily enhanced.

As discussed in section 3.1.7 the discharge of springs and seeps in the Cement Creek watershed may have decreased due to dewatering of the Sunnyside Mine. However, the base flow of

Cement Creek below Gladstone is now equal to or greater than the pre-mine base flow due to the discharge from the American Tunnel.

4.2 Mine Hydrology

4.2.1 Open Channel Flow Within the Underground Workings

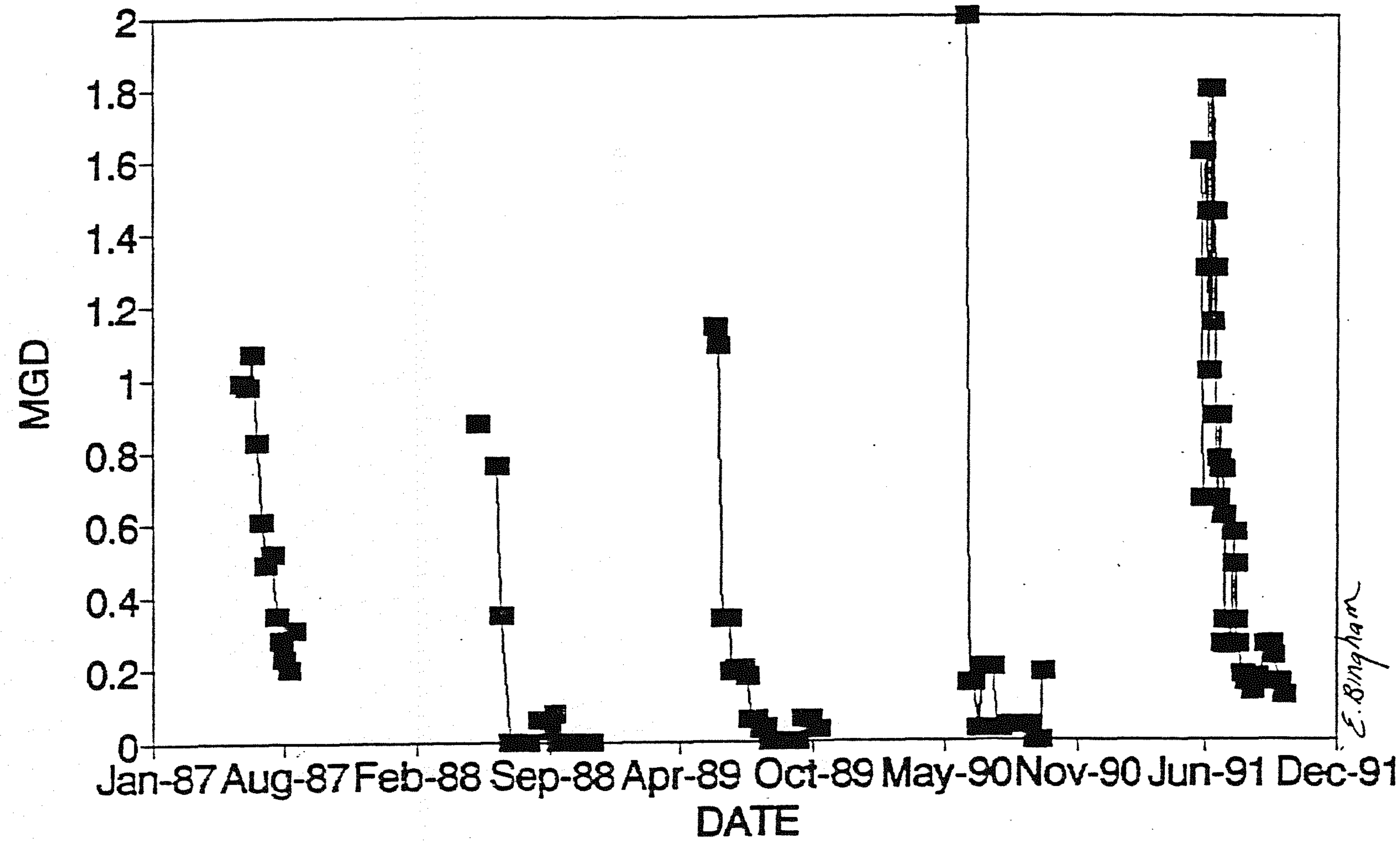
A considerable volume of water moves through the underground workings of the Sunnyside Mine. In the upper workings of the mine (F level and above) the majority of this water results from the capture of surface drainages and shallow perched ground water in the Sunnyside Basin. At the level of the American Tunnel (the lowest level of the mine) most of the water drains from the ground-water flow system.

A large percentage of the surface water from the head of Eureka Gulch drains into the underground workings of the Sunnyside Mine via the Lake Emma Hole and other places where workings intersect the land surface. The F level is a major haulage level and most stopes have a floor on that level. Hence, the majority of surface water entering the mine moves down to F level and then flows along F level and out of the Terry Tunnel. Mr. Larry Perino (present Superintendent of Technical Services at the Sunnyside Mine) made a visual estimate that flow from the Terry Tunnel ranged from 5 gpm in autumn to 100 gpm during spring runoff in 1978. After 1978, additional working of near-surface veins resulted in opening the Lake Emma Hole and self-stoping of other workings to the surface. As a result of the increased surface drainage, the measured flow from the Terry Tunnel now varies from 82 gpm in autumn to at least 1400 gpm during spring runoff.

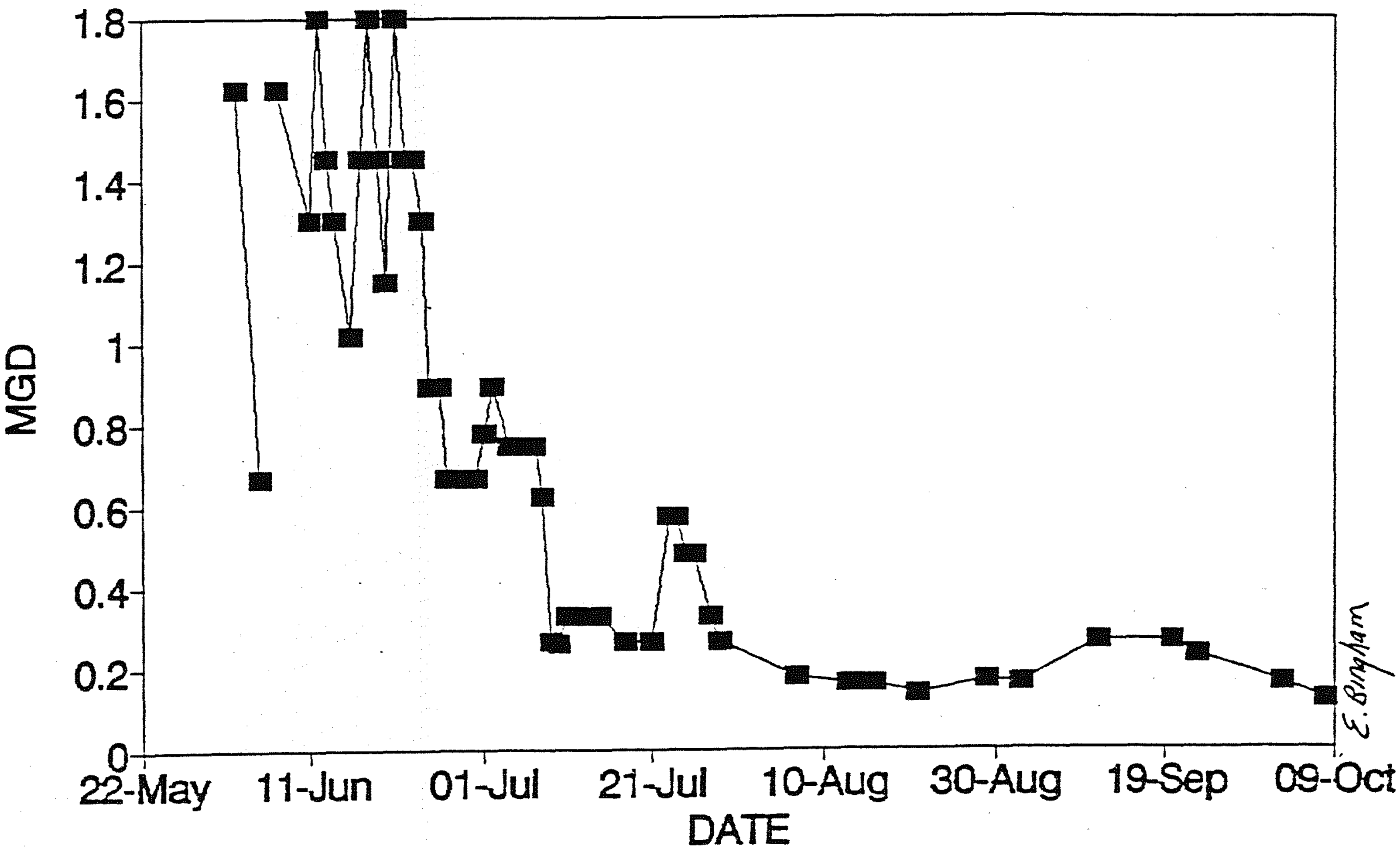
Figures 7 and 8 illustrate the present seasonal variation in flow from the Terry Tunnel. Flow from the Terry Tunnel is measured with an "H" flume below the settling ponds. Flow measurements from 1988 through fall of 1990 may be somewhat underestimated due to pond leakage (which is now insignificant) and inadequate leveling of the flume. No measurements are taken during winter and spring because the access road to the Terry Tunnel is typically impassible until late May. Figure 7 shows a peak flow in early June, but it is possible that the peak flow may have occurred prior to the first gauging in some prior years.

Flow from the American Tunnel is much more constant than flow from the Terry Tunnel. Figure 9 is a hydrograph of flow rates from the American Tunnel as measured using a Parshall flume downstream of the settling ponds at Gladstone. Flows less than 1.8 million gallons per day (mgd) or greater than 2.6 mgd are probably caused by pond cleaning activities. Flow rate from the American Tunnel is relatively constant throughout the year because the overwhelming majority of the flow originates as ground-water discharge (from fractures), rather than as surface drainage into the mine workings.

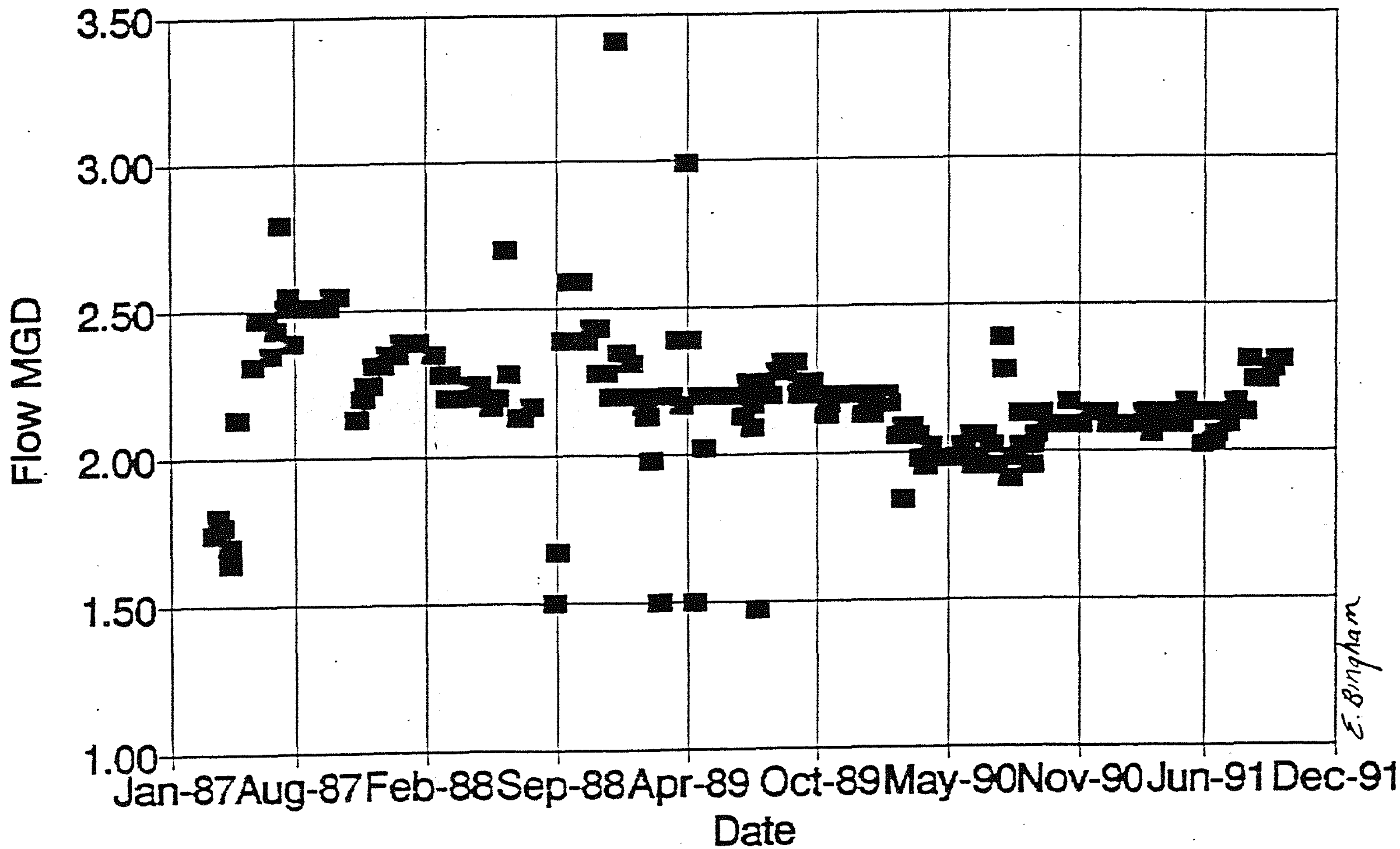
Flow measurements with a pygmy meter at the lime treatment plant just downstream of the portal of the American Tunnel (Table 3) shows a flow rate approximately 35% greater than the flow rate below the settling ponds (Figure 9). The reason for the difference is presently under investigation by SJCMV.



San Juan County Mining Venture Silverton, Colorado	DATE: 10/22/91
	DRAWN: DRD
Hydrograph of Flow from the Terry Tunnel: 1987-1991	CHECKED: MDS
	APPROVED: F. Fox
	DWG NO:
	PROJ.: 464110381
Hydro-Search, Inc. HYDROLOGISTS-GEOLOGISTS-ENGINEERS	**Figure 7**



San Juan County Mining Venture Silverton, Colorado	DATE: 10/22/91
Hydrograph of Flow from the Terry Tunnel: Detail of 1991	DRAWN: DRA
	CHECKED: MDS
	APPROVED: F. Fox
	DWG NO:
	PROJ.: 464110361
Hydro-Search, Inc.	Figure 8



NOTE

1. Flows measured at outlet of settling pond.

San Juan County Mining Venture Silverton, Colorado	DATE: 02/11/92 DRAWN: ARD CHECKED: MDS APPROVED:
Hydrograph of Flow from the American Tunnel: 1987-1991	DWG NO: PROJ.: 464110361
Hydro-Search, Inc. HYDROLOGISTS–GEOLOGISTS–ENGINEERS	**Figure 9**

1800819

ED_000552_00032415-00043

Table 3. Measured Flows in the American Tunnel	
Footage from Portal [1]	Flow Rate [2] (gallons per minute)
8150	620
7350	590
6400[3]	930
3420	890
2700	1350
2400	1470
0[4]	2160

1 Footages are "track repair footages" as marked on the wall of the American Tunnel and are approximate.

2 Flow was measured with a pygmy flow meter by Evelyn Bingham and Guy Lewis of SJCMV on October 2 - 3, 1991.

3 This measurement point is near the property line between SJCMV and Gold King.

4 Measurement was actually just upstream of the lime treatment plant.

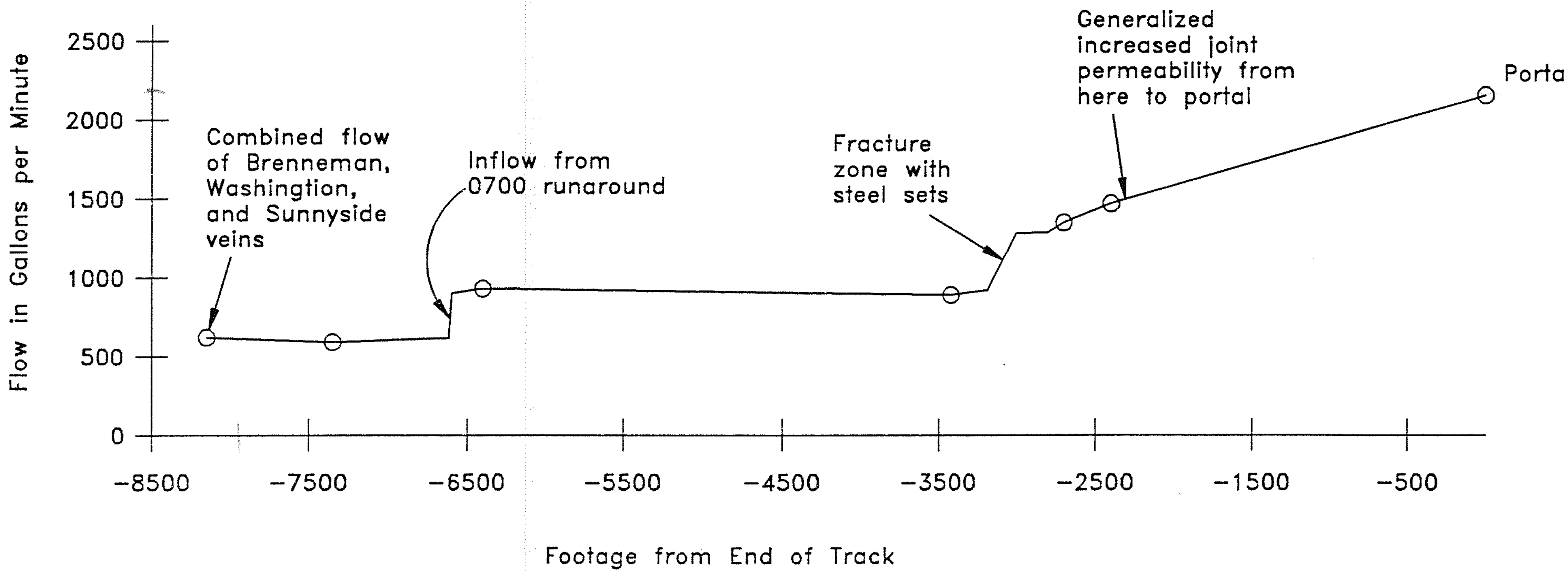
In the deeper parts of the American Tunnel (farther than approximately 2500 feet from the portal) the majority of water transmitted to the tunnel originates from a few fracture zones (Figure 10). Major permeable zones include the Washington vein (190 gpm), the Brenneman vein (200 gpm) the Sunnyside vein (180 gpm), a fracture zone at the 0700 runaround (approximately 340 gpm), and a fracture zone located 3020 to 3220 feet from the outside end of the track (approximately 400 gpm).

Within approximately 2500 feet of the portal minor joints transmit a significant amount of water. The increased permeability of the minor joints is due to a decrease in overburden pressure near the portal. This zone of generalized permeability accounts for approximately 32% of the flow leaving the portal.

On October 2-3, 1991 flow measurements showed 930 gpm of flow from the American Tunnel originated on SJCMV property. More than half (57%) of the discharge of the American Tunnel, amounting to 1230 gpm, entered the tunnel downstream of the property line.

4.2.2 Chemistry of Mine Waters

Most of the water entering the American Tunnel is ground water draining from fractures. This ground water locally contains relatively high concentrations of lead, zinc, cadmium, iron, and manganese. The chemistry of water entering the American Tunnel is discussed in further detail in section 3.1.5. Water discharging from the American Tunnel has a mean field pH value of 6.4, and a mean laboratory pH value of 5.4. Mean laboratory conductivity is 1,870 micro-mhos



EXPLANATION

○ Flow Measurement Points

NOTES

1. Footages are distance from end of track as marked on the wall of the American Tunnel and are approximate. The end of track is just outside of the American Tunnel portal.

2. Flow was measured with a pygmy flow meter by Evelyn Bingham and Guy Lewis of SJCMV on October 2–3, 1991.

San Juan County Mining Venture Silverton, Colorado	DATE: 02/13/92
	DRAWN: KEK
Flow Profile Along the American Tunnel	CHECKED: MDS
	APPROVED: F. Fox
	DWG NO:
	PROJ.: 464110361
Hydro-Search, Inc.	Figure 10

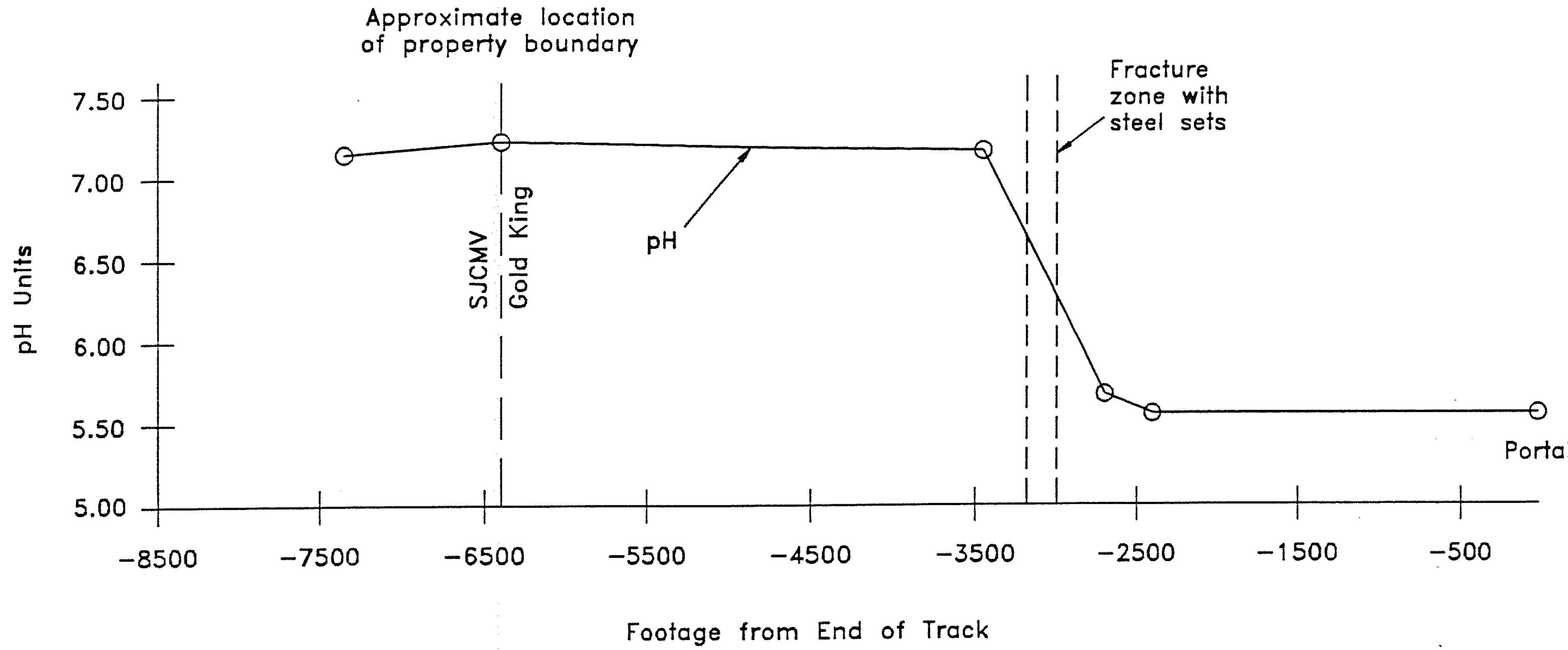
per centimeter. Mean values also indicate that the water has elevated concentrations (on a total metal basis) of cadmium, copper, iron, lead, manganese and zinc with respect to Colorado water quality standards (1986) for domestic water supplies.

The majority of the total metals load and the acid entering the American Tunnel originates downstream of the SJCMV property line. Figures 11, 12, and 13 are profiles of water chemistry along the American Tunnel. Figure 11 shows that on October 2 and 3, 1991 the flow in the American Tunnel had a nearly neutral pH until it encountered water entering from the fracture zone at the "steel sets" between 3020 and 3220 feet from the end of the track. Water from the steel sets fracture zone was sufficiently acidic to reduce the pH of the overall flow to approximately 5.5.

The total load of metals carried by a stream is the flow rate times the total metals concentrations. Figure 12 shows that the total metals load of iron, zinc, and manganese in American Tunnel ditch water dramatically increases after the steel sets fracture zone. The load of iron, zinc, and manganese continues to increase at a lesser rate throughout the last 2500 feet of the American Tunnel where dripping water enters the tunnel from relatively minor joints.

Figure 13 shows that the total metals load of copper and cadmium in American Tunnel ditch water also increases at the steel sets fracture zone. The load of cadmium does not increase downstream of this point, but the load of copper continues to increase in the last 2500 feet of the tunnel.

1800819



EXPLANATION

○ Sample collection points

NOTES

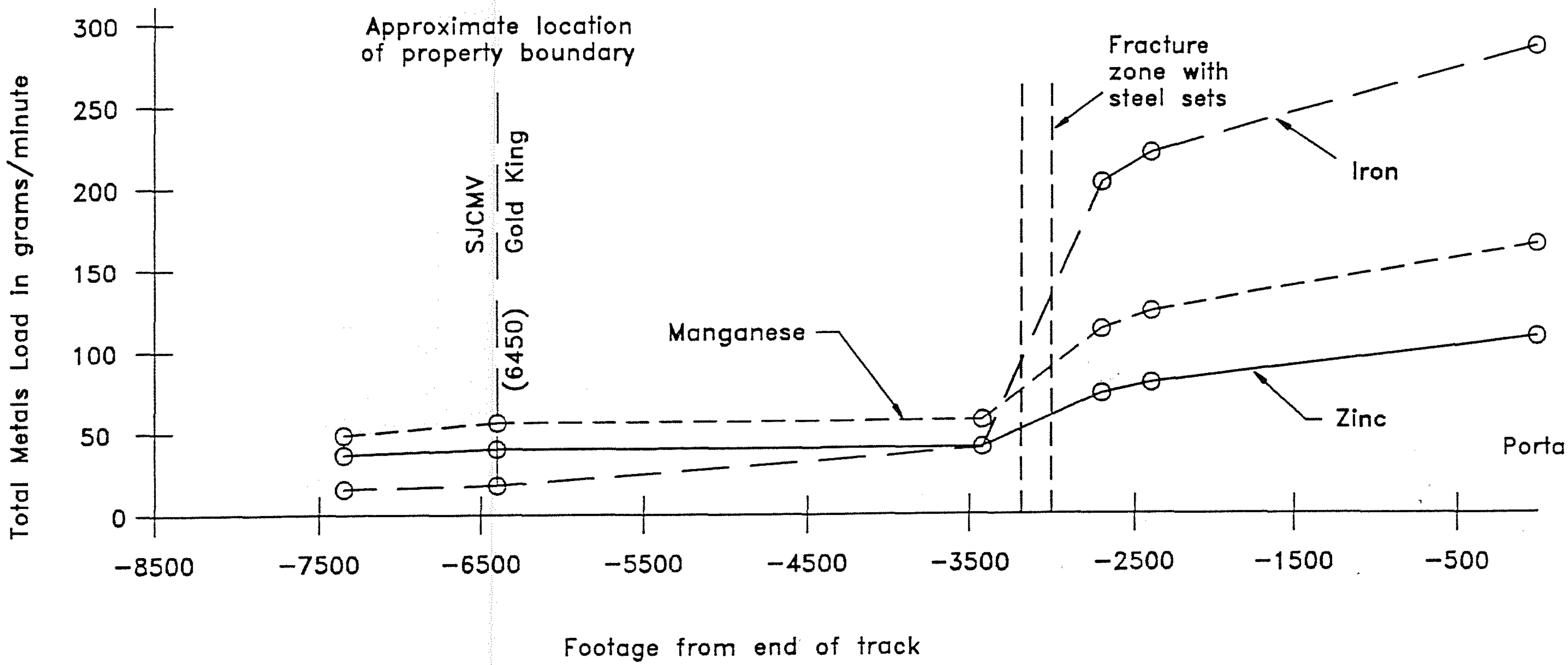
1. Footages are distance from end of track as marked on the wall of the American Tunnel and are approximate. The end of track is just outside of the American Tunnel portal.

2. Samples were collected by Evelyn Bingham and Guy Lewis of SJCMV on October 2–3, 1991.

3. Lab pH measured by Inter-Mountain Laboratories, Inc. of Farmington, NM.

San Juan County Mining Venture Silverton, Colorado	DATE: 01/21/92
	DRAWN: KEK
Profile of pH in the Drainage Ditch of the American Tunnel	CHECKED: MDS
	APPROVED:
	DWG NO:
	PROJ.: 464110361
Hydro-Search, Inc. HYDROLOGISTS–GEOLOGISTS–ENGINEERS	Figure 11

ED_000552_00032415-00048



EXPLANATION

○ Water Sampling Points

NOTES

1. Footages are distance from end of track as marked on the wall of the American Tunnel and are approximate. The end of track is just outside of the American Tunnel Portal.

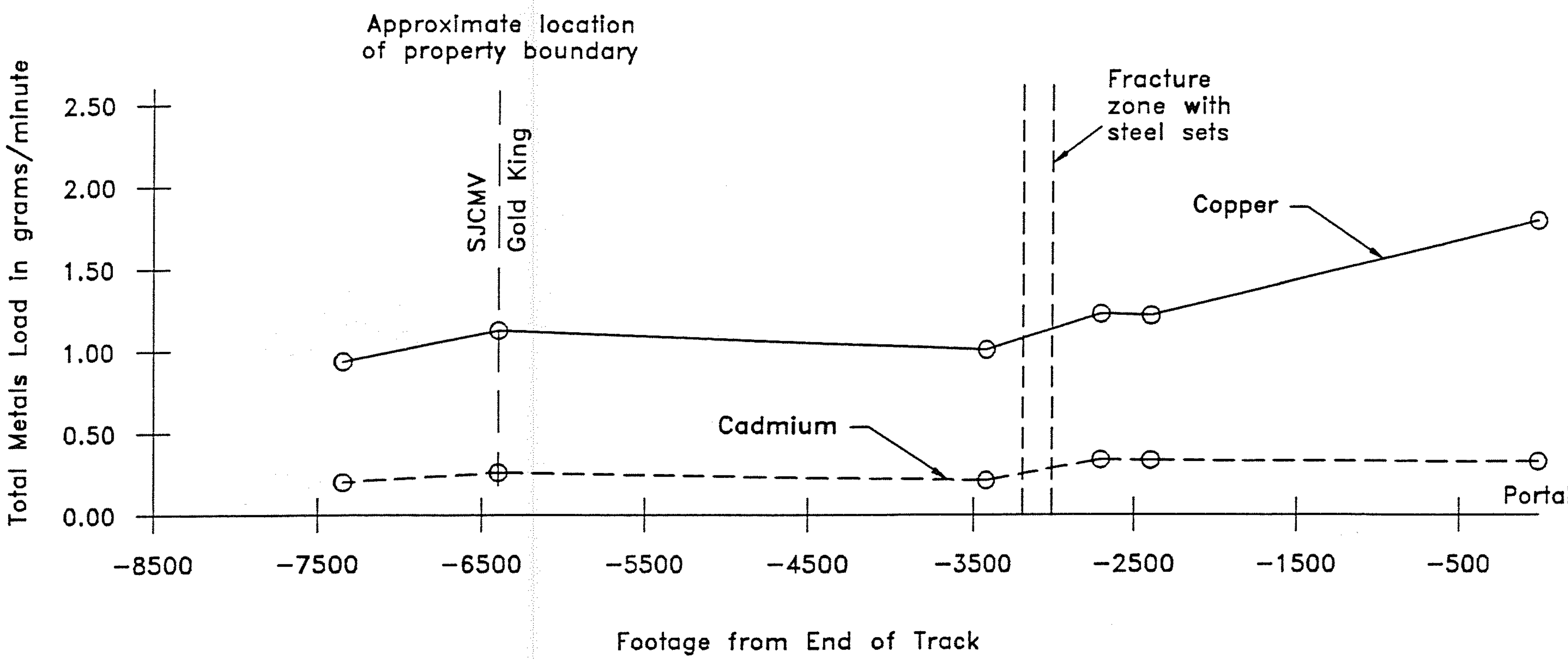
2. Samples were collected by Evelyn Bingham and Guy Lewis of SJCMV on October 2–3, 1991.

3. Analysis for total metals by Inter– Mountain Laboratories, Inc. of Farmington, NM.

San Juan County Mining Venture Silverton, Colorado	DATE: 01/21/92 DRAWN: KEK CHECKED: MDS
Load of Mn, Fe, and Zn Carried in American Tunnel Ditch	APPROVED: J. Fox DWG NO: PROJ.: 464110361
Hydro-Search, Inc. HYDROLOGISTS-GEOLOGISTS-ENGINEERS	**Figure 12**

1800819

ED_000552_00032415-00049



EXPLANATION

○ Water sampling points

NOTES

1. Footages are distance from end of track as marked on the wall of the American Tunnel and are approximate. The end of track is just outside of the American Tunnel portal.

2. Samples were collected by Evelyn Bingham and Guy Lewis of SJCMV on October 2-3, 1991.

3. Analysis for total metals by Inter-Mountain Laboratories, Inc. of Farmington, NM.

San Juan County Mining Venture Silverton, Colorado	DATE: 01/21/92 DRAWN: KEK CHECKED: MJYC APPROVED: 7,7oy DWG NO: PROJ.: 464110361
Load of Copper and Cadmium Carried in American Tunnel Ditch	
Hydro-Search, Inc. HYDROLOGISTS-GEOLOGISTS-ENGINEERS	**Figure 13**

1800819

ED_000552_00032415-00050

Water discharging from the Terry Tunnel is slightly acidic and contains elevated concentrations of some metals. The mean pH values for field and laboratory measurements are 5.9 and 5.7, respectively. However, the 1991 sampling shows a noticeable drop in the pH values. The mean values for total metal concentrations are all higher than the mean values for the American Tunnel with the exceptions of iron and manganese which were not analyzed.

Chemistry of the Terry Tunnel discharge water varies according to changes in surface water inflow to the upper levels of the mine. The rate of surface water inflow depends upon both daily and seasonal precipitation, and rate of snowmelt.

4.2.3 Existing Treatment Facilities - Sunnyside Mine

On Wednesday, July 31, 1991, Simon Hydro-Search was given a tour of the Sunnyside Mine's two lime precipitation systems at the American Tunnel and Terry Tunnel portals. Discharge from the American Tunnel is directed to a sump in the lime plant where lime is added to precipitate heavy metals. The tunnel discharge waters and the lime are allowed to mix in the turbulence created by the inflow to the sump. Discharge from the lime plant sump is by gravity flow to the first of four sedimentation ponds. None of the ponds are lined. A non-anionic polymer (Polypure N130) is added to the lime plant discharge somewhere in the 400 feet of pipeline between the sump and Pond No. 1. This addition of polymer facilitates the precipitation of heavy metals and has been accomplished by running a tube down the discharge pipe from the lime plant sump. However, the exact location of the tube end in the pipeline is unknown.

The discharge into Pond No. 1 is through a perforated pipe which runs along the east side of the pond. A brown sludge precipitates as water moves from east to west in Pond No. 1. The sludge settles out before it reaches the discharge pipe at the west end. The cleaning of Pond No. 1 occurs about every seven weeks and takes about one week to complete. Discharge is diverted to Pond No. 2 while Pond No. 1 is being cleaned. Pond No. 2 is cleaned once every year. All sludge is transported in tanker trucks to the tailings facility near the Mayflower Mill.

The discharge from Pond No. 4 is directed through a Parshall flume before it reaches Cement Creek. Flow rate and water quality samples are taken at the flume every week and reported to the Colorado Department of Health (CDH) once a month as required by the mine's NPDES permit. The rocks just below the flume outlet and the inside walls of the flume are coated with a black precipitate. This precipitate is probably derived from the manganese in the water which is not included in the treatment requirements of the mine's NPDES permit. For the last three years since the mine has been monitoring the treated discharge water from the American Tunnel, all discharge requirements have been met except for aquatic toxicity. The reason for the failure of the aquatic toxicity test is unknown. This is the prevailing condition throughout the Silverton Caldera including the water supply for Silverton.

Cement Creek is monitored for water quality and flow rate at two locations on a monthly basis pursuant to Colorado Mined Land Reclamation (MLR) requirements. The typical pH values at these two sites also are presented in Appendix C.

Discharge from the Terry Tunnel is highly variable and is dependent upon surface water inflow to mine workings from precipitation and snowmelt. Monitoring and treatment of the Terry Tunnel effluent is only conducted from late spring to early fall because the tunnel portal is inaccessible during the winter. Discharge from the Terry Tunnel is typically low during the winter months. Treatment consists of lime addition between the portal and the first of two sedimentation ponds. Pond No. 1 has been lined with recompacted fines. An "H" flume has been installed below Pond No. 2 for flow rate measurements. The NPDES discharge requirements for the Terry Tunnel effluent are less stringent than for the American Tunnel.

4.3 Present Surface-Water Hydrology

4.3.1 Surface-Water Flow

The measured flow rate (1987-1991) of the North Fork of Cement Creek just above Gladstone ranges between 15.7 mgd at the end of May to 0.23 mgd at the end of October (see Appendix C). Just below Gladstone this flow is augmented by the flow of the South Fork of Cement Creek which is not measured, and by the flow from the American Tunnel portal which is approximately 3.1 mgd (measured October 2-3, 1991).

The measured flow (1987-1991) of Eureka Creek above the Terry Tunnel portal varies from 5.2 mgd at the end of May to 0.05 mgd at the end of October. This flow is augmented by flow from the Terry Tunnel which ranges from 2.0 mgd in early June to 0.12 mgd in late October. The flow in Eureka Creek is also augmented by flow from McCarty Basin and downstream tributaries.

The measured flow in the Animas River (1986-1991) near the Mayflower Mill ranges from 116 mgd in April to 17.6 mgd in late October.

4.3.2 Surface-Water Chemistry

Present surface-water chemistry is influenced by the natural (pre-mining) surface-water chemistry as described in section 3.2.2, and the impacts of man, principally mining. The chemistry of the flows from the Terry Tunnel and American Tunnel is described in section 4.2.2. In addition to the workings of the Sunnyside Mine, there are numerous other mine workings which are not controlled by SJCMV located upstream of the Sunnyside portals including the Ben Franklin in Eureka Gulch, and the following mines in the Cement Creek watershed: the Big Colorado, Silver Ledge, Black Hawk, Gold King, Lead Carbonate, Red and Bonita, Adams, Pride of Bonita, Mogul, and Queen Anne.

The waters in Cement Creek and Eureka Creek have been sampled just above the American Tunnel and the Terry Tunnel, respectively, since 1987. The water of Cement Creek above the American Tunnel discharge is acidic, with pH values between 3 and 5 and a mean pH of 4.0. Natural ground-water seepage and mine drainage both contribute to this acidity; however, the percentage of each contribution would require additional sampling and analyses to quantify. The water of Eureka Creek above the Terry Tunnel discharge is neutral with a mean pH of 7.1.

5.0 REFERENCES CITED

Bird, A. G., 1986, Silverton Gold, The story of Colorado's Largest Gold Mine, 137 p.

British Columbia Acid Mine Drainage Task Force, 1989, Draft Acid Rock Drainage Technical Guide, Vol. 1.

Burbank, W.S.,1960, Pre-ore propylitization, Silverton Caldera, Colorado, U.S. Geol. Survey Prof. Paper 400-B, p. B12-B13.

Burbank, W.S., and Luedke, R.G., 1961, Origin and Evolution of Ore and Gangue-Forming Solutions, Silverton Caldera, San Juan Mountains, Colorado, *in* Short papers in geology and hydrology, U.S. Geol. Survey Prof. Paper 424-C, p. C7-C11.

Burbank, W.S., and Luedke, R.G., 1964, Geology of the Ironton Quadrangle, Colorado, U.S. Geol. Survey Geol. Quad. Map GQ-291.

Burbank, W.S., and Luedke, R.G., 1969, Geology and Ore Deposits of the Eureka and Adjoining Districts San Juan Mountains, Colorado, U.S. Geol. Survey Prof. Paper 535, 70 p.

Casadevall, T., and Ohmoto, H., 1977, Sunnyside Mine, Eureka mining district, San Juan County, Colorado: Geochemistry of gold and base metal ore deposition in a volcanic environment, Econ. Geology, v. 72, p. 1285-1320.

Driscoll, F.G., 1986, Groundwater and Wells, Second Edition, Johnson Division, St. Paul, Minnesota, 1089 p.

Freeze, R.A., and Cherry, J.A., 1979, Groundwater, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 604 p.

Garrells, R.M. and C.L. Christ, 1965, Solutions, Minerals, and Equilibria, Harper and Row, New York, 449 p.

Gebert, W.A., Graczyk, D.J., and Krug, W.R., 1987, Average Annual Runoff in the United States, 1951-80, Hydrologic Investigations Atlas HA-0710.

Iorns, W.V., Hembree, C.H., Phoenix, D.A., and Oakland, G.L., 1964, Water Resources of the Upper Colorado River Basin - Basic Data, U.S. Geol. Survey Prof. Paper 442, 1036 p.

Langbein, W.B., et al., 1949, Annual Runoff in the United States, U.S. Geol. Survey Circular 52, 14 p.

Langston, D.J., 1978, The Geology and Geochemistry of the Northeasterly Gold Veins, Sunnyside Mine, San Juan County, Colorado, Colorado School of Mines/M.S. thesis, 153 p.

Larsen E.S., and Cross, W., Geology and Petrology of the San Juan Region Southwestern Colorado, U.S. Geol. Survey Prof. Paper 258, 303 p.

Lohman, S.W., 1979, Ground-Water Hydraulics, U.S. Geol. Survey Prof. Paper 708, 70p.

Luedke, R.G., and Burbank, W.S., 1960, Ring-Fractured Bodies in the Silverton Caldera, Colorado, *in* Short papers in Geology and Hydrology, U.S. Geol. Survey Prof. Paper 400-B, p. B13.

Luedke, R.G. and Burbank, W.S., 1987, Geologic Map of the Handies Peak Quadrangle, San Juan, Hinsdale and Ouray Counties, Colorado, U.S. Geol. Survey Geol. Quad. Map GQ-1595.

Meiman, J.R. and Grant, L.O., 1974, Snow-Air Interactions and Management of Mountain Watershed Snowpack, Completion Report for OWRR Project No. B-073-COLO, Environmental Resources Center, Colorado State University, 33 p.

Rhoda, F., 1984, Summits to Reach: Report on the Topography of the San Juan Country, edited by Mike Foster, Pruett Publishing Company, Boulder, Colorado, 159 p.

Siskind, D.E. and R.R. Fumanti, 1974, Blast-Produced Fractures in Lithonia Granite, Report of Investigations 7901, U.S. Bureau of Mines, 38 p.

Steven, T.A., and Lipman, P.W., 1976, Calderas of the San Juan Volcanic Field, Southwestern Colorado, U.S. Geol. Survey Prof. Paper 958, 35 p.

Sunnyside Gold Corp.,1988, Structure and Ore Deposits of the Sunnyside Mine, Silverton, Colorado, in Epithermal Base-Metal and Precious-Metal Systems, San Juan Mountains, Colorado, Society of Economic Geologists, Guidebook Series Vol. 3.

Todd, D.K., 1980, Groundwater Hydrology, Second Edition, John Wiley & Sons, New York, 535 p.

Varnes, D.J., 1963, Geology and Ore Deposits of the South Silverton Mining Area, San Juan County, Colorado, U.S. Geol. Survey Prof. Paper 378-A, 53 p.

Worsey, P.N., 1985, Measurement of Blast Induced Damage in Wall Rock for a Selection of Underground Perimeter Blasting Techniques, in Proceedings of the Eleventh Conference on Explosives and Blasting Techniques, Society of Explosives Engineers, pp. 175-189.

Worsey, P.N., 1986, The Quantitative Assessment of Blast Damage in Highway Rock Cuts and Tunnel Profiles by Seismic Refraction Surveys, Rock Mechanics and Explosives Research Center, University of Missouri, Rolla, Missouri, 22 p.